

Weed management in Indian Agriculture: current scenario and way forward

A. R. Sharma¹, N. T. Yaduraju² and T. K. Das³

Indian Agricultural Research Institute, New Delhi 110 012

Weed control in crop lands was not considered a major issue in Indian agriculture during the pre-independence period. It was only in the 1950s and specially, after the introduction of dwarf-statured varieties of wheat and rice in the 1960s that the issues related to weeds attracted attention of the agriculturists. In the present times, weed management is the most important operation concerning farmers. The labour scarcity, high cost of production, invasion of new weed species, faulty application of chemical herbicides, and lack of awareness and extension efforts are the key issues that have brought the subject to the forefront. In fact weeds are impacting not only agricultural production systems but are also a major concern in the water-bodies, city dwellings, road sides and railway lines, forest and grazing lands. It is feared that weed infestations will increase in future due to the transformations happening in crop production and neglect of non-agricultural lands. While suitable technologies including use of herbicides are now available to keep the weeds under check, there is a need to educate the stakeholders about the advances in weed management for increasing productivity, restoring biodiversity and societal upliftment.

Key words: Agriculture, Current Scenario,. Management, Weed

Weeds are one of the major biotic constraints in agricultural production. As per available estimates, the weeds cause up to one-third of the total loss in crop yield, besides impairing produce quality and various kinds of health and environmental hazards. Weeds are ubiquitous and problematic virtually in all ecosystems including agriculture, plantation crops, grasslands, forestry, sanctuaries, water-bodies, wastelands, public amenity areas etc. Therefore, weeds impact everyone including non-farmers and city dwellers. The losses caused by weeds are enormous but often go unnoticed as the effect is mostly unseen. Because of this, the farmer develops a fatalistic attitude towards weeds and gives them the last priority when it comes to their management. As per the available estimates, weeds contribute as much as 37% of the total loss in production

caused by all the agricultural pests in India. On a conservation estimate, 10 to 15% of the crop production is lost every year due to weeds, amounting to well over ₹ 1,00,000 crore.

Despite the development and adoption of weed management technologies, the weed infestations are virtually increasing in cropped and non-cropped lands. This is due to adoption of high-input and intensive cropping systems; neglect and discontinuation of some of the traditional practices like intercropping, mulching and crop rotations involving legumes; shift in weed flora due to adoption of fixed cropping systems and management practices including herbicides; development of herbicide resistance in weeds e.g. *Phalaris minor* in the 1990s; growing menace of weedy rice in many states and *Orobanche* in mustard growing areas; invasion by alien weeds like *Parthenium*,

Lantana, *Ageratum*, *Chromolaena*, *Mikania* and *Mimosa* in many parts of the country; impending climate change favouring more aggressive growth of weed species, and herbicide residue hazards. This suggests that weed problems are dynamic in nature, requiring continuous monitoring and refinement of management strategies for alleviating their adverse effects on agricultural productivity and environmental health.

Research work on weed management is going on in India for the past 6 decades since the initiation of a coordinated scheme in principal crops like rice, wheat and sugarcane in 1952. This work was strengthened with the launching of All India Coordinated Research Project on Weed Control in 1978, which is now being implemented all over the country. The establishment of National Research Centre for Weed

Table 1. Focussed areas of research in weed science in India

Before and during 1980s	• Weed survey, documentation, crop-weed competition • Herbicide screening and use in cereal crops like rice, wheat and maize
1990s	• Invasive weeds like <i>Phalaris</i>, <i>Parthenium</i>, <i>Lantana</i> spp. • Herbicide screening and use in pulses, oilseeds and commercial crops
2000s	• Systems approach to weed management • Weed control in horticultural and plantation crops • Herbicide residues and resistance development in weeds • Aquatic weeds like water hyacinth and <i>Salvinia</i> • Herbicide tolerant crops – some experiments on maize, mustard, cotton and soybean
Presently	• Low-dose high-potency herbicide molecules and mixtures • Crop-weed interaction under changing climate • Weed management under conservation agriculture, organic farming and precision farming systems

Science in 1989 at Jabalpur and its upgradation as Directorate of Weed Science Research in 2009 (renamed as Directorate of Weed Research in 2014) was a major step forward to undertake systematic research and development programmes on weed management in a holistic and comprehensive manner by adopting multi-disciplinary approach. Over the last 4 decades, sound weed management technologies were developed and promoted in the country, that helped in reducing costs and drudgery involved in weed control, and increasing crop productivity. Weed science research in India has undergone a transformation over the years (Table 1).

Current status of weed management

Manual and mechanical removals were most predominant methods of weed management in India. However, these were not very effective, particularly under adverse soil and weather conditions. Manual weeding is highly labour-intensive, involves a lot of drudgery and is unfortunately mostly done by women. Currently, the farming is being predominantly practised by old men and women whereas youth are not taking interest. Modernization of agriculture involving the use of chemicals, machinery and other modern technologies may halt this trend. Increasingly more and more farmers are opting for herbicides mainly due to increased labour cost and their unavailability. Farmers in India are now demanding and using herbicides for weed control than ever before. However, the non-availability of good quality chemicals and

adoption of faulty application techniques due to lack of awareness are often noticed, leading to poor efficacy.

Globally, herbicides are the leading group of pesticides with 45% of the total consumption compared to a mere 18% in India (Fig. 1 and 2). The herbicide share in India is expected to rise faster in the years to come. In fact, non-selective herbicides are now being used on the highways, railways, public amenity areas, and in irrigation canals and drainage ditches for clearance of unwanted vegetation. Herbicide application is more common in crops like wheat, rice, soybean, maize, and plantation crops like tea. Their use in other crops including pulses, oilseeds, vegetables and spices is on the rise. Growing weed infestation is becoming a major concern of various stakeholders including the farmers. In fact, in some cropped situations, managing weed menace is more difficult than nutrient or water management. Farmers are in dire need of suitable cost-effective weed management technologies, driving them towards farm mechanization and chemical weed control.

Unlike other pesticides, herbicides by and large have lower toxicity (higher LD₅₀ values) and reported to leave no or very low levels of residues in the soil, crop produce and ground water. There are however, concerns of residual effect of herbicides on susceptible intercrops or succeeding crops and development of herbicide resistance in weeds. It is well documented that integrated weed management approach involving different methods - specifically the

cultural methods is more sustainable. However, it is not being adopted by majority of the farmers for a variety of reasons. Weed management has traditionally been a part of agronomy. In the recent past, however, weed science has grown into a discipline of its own, drawing knowledge from varied disciplines such as botany, entomology, pathology, microbiology, soil science, biotechnology, engineering etc., which is essential to address the problem of weeds in a holistic way.

Weed problems are dynamic in nature and are likely to be more serious in the coming decades due to the:

- Adoption of dwarf high-yielding varieties and hybrids
- High-input agriculture
- Altered agronomy – discontinuation of intercropping, mulching and adoption of zero-till, organic farming systems
- Monocropping and fixed cropping systems, causing shift in weed flora; development of herbicide resistance in weeds;
- Herbicide residue hazards;
- Growing infestation of weedy rice, parasitic and other obnoxious weeds;
- Globalization and invasion of alien weeds.
- Implications of climate change; and Lack of quality human resource in weed science.

Operating environment

Stakeholders express serious concerns about weed management in real field situations. The farmers are in dire need of cost-effective weed management technologies for increasing productivity and profitability. Following issues have emerged based on interaction with various stakeholders: non-availability of labour for weed control ;rising costs of manual weeding ; invasion of new weed species; application techniques of herbicides ; combined use of herbicides with other pesticides; non-availability of herbicides and mechanical tools; spurious and costly herbicides; large packings of herbicides; registration of new molecules ; lack of awareness and extension efforts; and weeds in

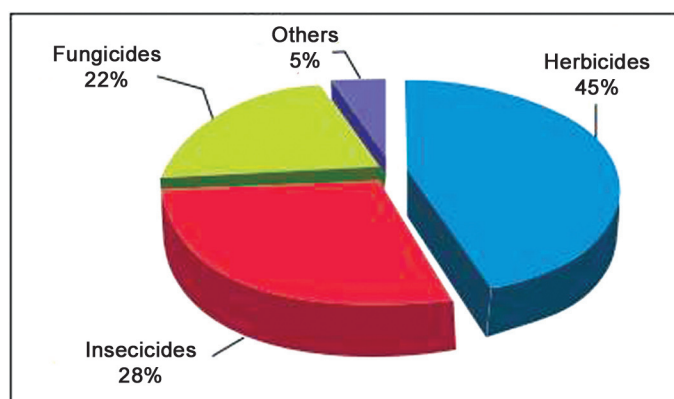


Fig 1. Global scenario of pesticide use

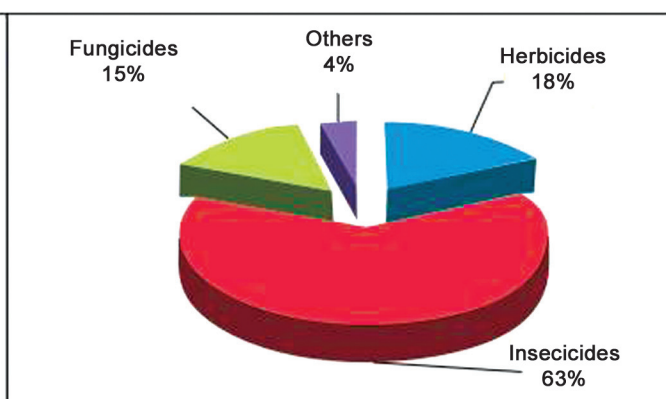


Fig 2. Indian scenario of pesticide use

no-man's lands.

Operating environment in the coming decades is likely to be more uncertain, complex and difficult for weed management. The scarcity of labour for manual operations will increase further, and chemical weed management will become more important. However, there will be increased instances of herbicide resistance development in weeds and occurrence of herbicide residue hazards with increased use of chemicals. It is likely that herbicide-tolerant crops might become a reality in Indian agriculture after some of the anticipated concerns are adequately addressed. Changing climate is an issue which will intensify weed problems considering the better adaptive behaviour of weeds compared with crop plants. Alternate production systems involving crops of high economic value, zero-tillage, fertigation, protected cultivation and other advanced technologies will become more predominant, and thus present an entirely different weed management scenario. Problematic weeds in non-cropped lands may further intensify due to their prolific regeneration and uncontrolled growth.

Herbicides have become a boon to the farmers in areas where the labour availability is limited and wages are high. The use of herbicides has been increasing in India enormously in the last few decades (Fig. 3). Herbicide use is expected to grow by 15 to 20 %, which would be higher than insecticides and fungicides. The major impact was found in north-western India where most of the agricultural operations are done by

migrant labourers. The advantages of herbicides over the other methods are appreciable in closely-planted crops like rice (*Oryza sativa*) and wheat. In many regions, these crops are sown by broadcasting, thus making manual weeding more difficult. Wheat (*Triticum vulgare* var. *aestivum*) and rice account for major share of the total herbicide consumption in the country. Herbicides are used on more than 20 million ha, which constitute about 10% of the total cropped area in the country. There is an urgent need for chemical-based technologies for managing weeds in pulses, rainfed areas, parasitic weeds like *Orobanche*, and weedy rice.

Herbicides registered in India

Presently 60 technical herbicides and 17 combination herbicides were registered for use in our country. Some herbicides, which were once registered are presently banned for use in agriculture owing to various problems, mainly related to their

adverse effect on human and animal health. All pesticides including the herbicides are toxic in nature, hence their irrational and injudicious use can cause damage to the user and the environment. However, it may be noted that herbicides as a group are relatively safer compared to other pesticides, especially insecticides. As per the WHO classification, globally 34% of the 158 insecticides fall under extremely hazardous and highly hazardous group when compared with only about 1.5% in case of herbicides. Under slightly hazardous group, the number of herbicides is two-fold higher as compared to insecticides. The number of herbicides that are unlikely to present acute hazard is as much as 41% of the total as compared to only 13% in case of insecticides (Table 2). For the pesticides registered for use in India, the situation is even more favourable in case of herbicides (Table 3). Of the 50 herbicides which are currently in use, none belongs to extremely

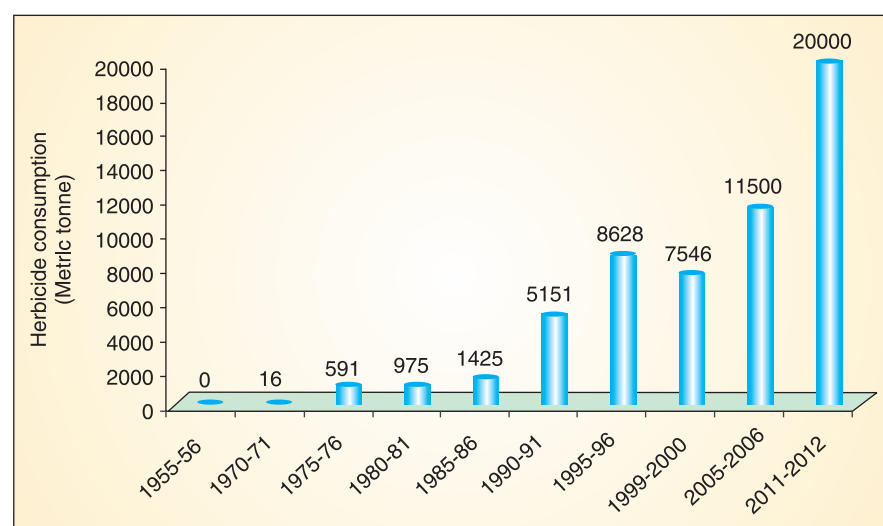


Fig. 3. Herbicide consumption in India between 1955-56 and 2011-12

Table 2. Number of pesticides registered globally belonging to different classes in toxicity classification of WHO

Pesticides	Toxicity class					Total
	1a Extremely hazardous	1b Highly hazardous	II Moderately hazardous	III Slightly hazardous	U Unlikely to present acute hazard	
Insecticides	15 (9.5)*	39 (24.7)	68 (43.0)	16 (10.1)	20 (12.6)	158
Fungicides	4 (2.9)	2 (1.4)	54 (38.6)	28 (20.0)	52 (37.1)	140
Herbicides	0 (0.0)	3 (1.5)	70 (34.3)	48 (23.5)	83 (40.7)	204
Other chemicals	8 (10.3)	14 (17.9)	20 (25.6)	11 (14.1)	25 (32.1)	78

*As % of total

Table 3. The number of pesticides registered in India belonging to different classes in toxicity classification of WHO

Pesticides	Toxicity class					Total
	1a Extremely hazardous	1b Highly hazardous	II Moderately hazardous	III Slightly hazardous	U Unlikely to present acute hazard	
Insecticides**	4 (4.7)*	12 (14.3)	41 (48.8)	10 (11.9)	17 (20.3)	84
Fungicides	0 (0.0)	1 (2.0)	21 (42.8)	6 (12.2)	21 (43.0)	49
Herbicides	0 (0.0)	0 (0.0)	16 (32.0)	12 (24.0)	22 (44.0)	50

*as % of total, **includes rodenticides and acaricides also

hazardous and highly hazardous group. About 44% of the herbicides are grouped under unlikely to present acute hazard, whereas only 20% of the insecticides come under this category.

Herbicides are chemicals which are used to kill unwanted (weeds) under cropped or non-cropped situations. The herbicide is a very important group of agro-chemicals without which modern profitable agriculture is not possible. However, there are some apprehensions in the minds of stakeholders about herbicide use in agriculture, e.g. (i) Herbicides are hazardous poisonous chemicals, (ii) Have adverse effects on soil, crop, water and environment, (iii) Leave toxic residues in food chain, (iv) Have adverse effect on useful flora and fauna, (v) Cause weed flora shift and resistance development, (vi) Displace labour, leading to unemployment, (vii) Reduce fodder availability as some weeds are fed to animals, and (viii) Reduce biodiversity. Most of these apprehensions were found to be exaggerated and ill-founded. Herbicides are quite safe if used judiciously and strictly as per the recommendations.

Recommendations

Herbicides and their applications

are distinctly different from other pesticides.

A few of distinguishing features are:

- Herbicides are inherently less toxic compared to other pesticides. The LD₅₀ value of herbicides is very high, meaning thereby that very high concentration is required for them to accumulate and be toxic in the environment. This is unlikely to be encountered at the recommended rates of application.
- Unlike other pesticides, herbicides are specific to the crop. Different chemicals are used in different crops often to control the same weed. For instance, to control barnyard grass while atrazine is used in maize, herbicide butachlor is recommended in rice.
- Application rate of herbicides is very specific. In other pesticides, high dose may not affect the crop, whereas herbicides applied at higher doses can significantly damage the crop. The selectivity is dose-dependent. At extremely high rates, most soil-applied herbicides may act as soil sterilants.
- Uniform application is very critical with herbicides. Herbicides are recommended on active ingredient basis. Farmers need to calculate the amount of commercial product required for his field. The required

quantity needs to be dissolved in water and applied uniformly over the given area. This requires some calculation which is dependent on capacity of the sprayer, nozzle type, the spraying pressure and the speed of application. The other pesticides are applied at recommended concentration (%).

- As herbicides are crop-specific, any spray drift reaching the susceptible crop plants grown in the adjoining fields is of some concern. One therefore has to be careful in ensuring that spraying is done at optimal weather conditions (especially wind) so that there is minimal damage to the susceptible crops growing nearby. Fine spray (with very small spray droplets) is prone to drift. This could be avoided or minimized by selecting the appropriate sprayer and nozzle.
- Herbicides in most crops are applied in the early part of growth period (within 30 days), while the insecticides are used throughout the growth period even after flowering and during ripening stages. Therefore, the herbicides are metabolized and degraded by the time crop reaches maturity leaving no residues in the soil or plant.
- With the possible introduction of herbicide-tolerant crops, farmers need to be educated about the dangers of using herbicides meant for HRCs on non-HRCs. This however, is not relevant in case of insecticides. For instance, all insecticides could be safely used on both Bt-cotton (the only commercialized GM crop in the country) and non-Bt cotton.

Future prospects

Following opportunities are available for weed management in Indian agriculture:

- Herbicides are becoming increasingly important for weed management due to labour scarcity in many parts of the country. Safer low-dose synthetic molecules of various modes of action are being introduced to replace conventional herbicides. New low-dose and high-potency molecules and formulations have become available in the last decade. It is expected that more

such new generation chemicals will become a reality in near future.

- Research on controlled release formulation is essential for precision weed management. The controlled release of herbicide molecules in application zones provides long-term control of weeds avoiding repeat application of herbicides. These formulations minimize herbicide residues in the environment, increase the efficacy and longevity of the herbicide by protecting it from environmental degradation, and decrease the application cost. Research and development of nano-herbicides and other slow release chemicals is continuing, and is expected to yield results in the coming years.
- Precision farming based on remote sensing techniques for site-specific weed management are being developed. This will greatly help in avoiding wastage of herbicides and minimize residue hazards.
- Herbicide-tolerant crops are being grown in many parts of the world. It is expected that such crops will be introduced into India in near future after the legitimate concerns are adequately addressed. This may change the spectrum of weed management programmes in India.
- Innovative production systems like conservation agriculture and organic farming are being advocated for enhancing resource-use efficiency, crop productivity and environmental sustainability. Weed management in such systems would require greatly enhanced knowledge and application.
- New generation machines for tillage, sowing, interculturing, spraying, harvesting and residue management are being developed, which will provide cost-effective means of weed management.
- Search of bioactive botanicals and microbial metabolites, which may act as lead molecules for herbicide development, is an essential component of weed management programme. Research on biotechnology can provide breakthrough for development of bioherbicides, which are host-specific and environment friendly. Similarly, new strains of bioagents

effective against problem weeds will be identified.

- Emphasis is being given to develop solar energy-aided microwave generating devices for the control of target weeds. The success of it may reduce herbicide consumption many folds. This device coupled with sensor technology will be the part and parcel of precision and automated weed control technology.
- New tools aimed at more effective transfer of technology for weed management are available in the era of ICT. Farmers will have easy and quick access for such tools in the coming decades. A weed management data repository and effective Management Information System will be needed.
- Efficient diagnostic techniques for monitoring herbicide residues would lead to safer chemical weed control and cleaner environment. Effective decontamination techniques for active and transformation products will provide opportunity for mitigation of residue hazards.
- Climate change research would provide further insights into crop-weed association, herbicide and bioagent efficacy for developing effective weed management technologies.
- Weed utilization techniques are available for effective conversion of weed biomass into enriched compost, medicinal use, bioremediation and industrial application.

WAY FORWARD

Continuous refinement of weed management technologies is essential to cut down production costs, and also in the light of ever changing socio-economic conditions of the farmers and international trade policies. Rapid expansion of weedy rice infestation, evolution of herbicide-resistant weeds, introduction of alien invasive weeds, lack of low-cost environment-friendly weed management technologies for water-bodies and for dryland farming systems, are some of the burning issues requiring immediate attention. Herbicides are going to become

increasingly popular in the coming years but the concern for herbicide residues and other environmental issues are also required to be suitably addressed. Development of suitable technologies to tackle the probable scenario that may emerge in the area of crop-weed competition due to increased atmospheric CO₂ concentration and subsequent global warming are the major future challenges. Herbicide-tolerant crops may be a possibility in the coming decades after the legitimate concerns are adequately addressed.

A holistic approach with multi-disciplinary, multi-locational and multi-institutional involvement would be imperative to tackle future weed problems in India. AICRP on Weed Management functioning under the Directorate of Weed Research is a great strength and will continue to be immensely useful in this regard. Efforts are needed to develop effective linkages with other sister institutions under ICAR as well as other scientific organizations like CSIR, DBT, DST and ISRO in formulating innovative research projects. Efforts also need to be made with IITs and IIITs to explore the possibility of utilizing the robotic and laser technology for weed control.

Scientists need to be trained in new areas like weed risk analysis, precision farming, herbicide residue estimation, C-sequestration, crop-weed modeling, climate change and biotechnology. Evaluation of new low-dose high-potency herbicide molecules and their methods of application for higher efficiency will be addressed in collaboration with the herbicide industry. More emphasis will be given on developing integrated weed management technologies involving non-chemical methods such as use of cover crops, weed suppressing crop cultivars and mechanical weeding tools. Basic research in areas like allelopathy and bio-herbicides which have relevance for practical weed management will be undertaken through collaborative arrangements with other institutes. Research on biological control of alien invasive weeds in non-cropped situations and aquatic bodies will be undertaken with the participation of

all stakeholders. Scientists will also be encouraged to undertake on-farm research trials in participatory mode and take part in technology development, refinement and transfer. Technologies developed will be refined and fine-tuned for their suitability in actual farmers' situations through on-farm trials, awareness campaigns, farmers' fair, farmers' training etc. The involvement and partnership of other line departments such as state departments of agriculture, NGOs, local administration and others will be ensured to achieve the goals. The technical programme for network research on management of aquatic and parasitic weeds, weed management in rainfed agriculture, horticultural crops need to be finalized after thorough interaction with collaborating organizations.

SUMMARY

Weed management in India is going on since 1952. The serious research in weed science was undertaken during 1970s when herbicides like 2,4 D, butachlor, isoproturon, atrazine were found highly effective in major cereal crops. This work was strengthened with the launching of All India Coordinated Research Project on Weed Control in 1978, and establishment of National Research Centre for Weed Science in 1989 at Jabalpur (renamed as Directorate of Weed Research in 2014). Globally, herbicides are the leading group of pesticides with 45% of the total consumption compared to a mere 18% in India. Wheat and rice account for major share of the total herbicide consumption in the country. At present 60 technical herbicides and 17 combination

herbicides are registered for use in our country. However, indiscriminate use of herbicides has increased instances of herbicide resistance in weeds and occurrence of herbicide residue hazards. Herbicide-tolerant crops might become a reality in Indian agriculture after addressing some of the anticipated concerns. Changing climate is an issue which will intensify weed problems. An integrated and holistic approach with multi-disciplinary, multi-locational and multi-institutional involvement would be imperative to tackle future weed problems in India.

¹Director of Research, Rani Lakshmi Bai CAU, Jhansi (Uttar Pradesh), ²Former Director, Directorate of Weed Research, Jabalpur, Madhya Pradesh 482 004 and ³Principal Scientist (Agronomy) Division of Agronomy, IARI, New Delhi 110 012. Corresponding authors' e mail: sharma.ar@rediffmail.com

Weeds management may enhance crop yield

J. S. Mishra¹

Weeds are serious threat to agricultural productivity, farmers' income, biodiversity, environment, and human and animal health. Weed management is still a major concern in farming despite development and adoption of weed management technologies. Therefore, development and dissemination of need-based improved and sustainable weed management technologies are needed to address the issues of emerging weed problems under changing climate scenario.

This special issue of *Indian Farming* provides detailed information on various aspects of integrated weed management. I compliment Directorate of Weed Research, Indian Society of Weed Science, and the contributors of special issue on 'Weed Science and Society: Challenges and Opportunities' for bringing out this publication. I am sure that this publication will be highly useful to the farmers, researchers, teachers, students and all those involved in weed management.

I am glad to know that Indian Society of Weed Science is bringing out a special issue of *Indian Farming* on the occasion of the ISWS Golden Jubilee International Conference on 'Weeds and Society: Challenges and Opportunities' being organized at Directorate of Weed Research, Jabalpur between 21 and 24 November, 2018. This special issue of *Indian Farming* contains the articles contributed by the eminent weed scientists of the country on various aspects of weed management and their impacts on farmers' income, environment and society.

¹Head, Division of Crop Research,
ICAR Research Complex for Eastern Region,
ICAR Parisar
P. O. Bihar Veterinary College,
Patna (Bihar) 800 014